CHAPTER II
ASSESSMENT OF DISPARITY IN ACCESSING RAILWAY STATIONS IN THAILAND: AN APPLICATION GEOGRAPHIC INFORMATION SYSTEM NETWORK ANALYSIS

2.1 Abstract

Ensuring that people from all regions in a country can easily access railway stations is a crucial objective in the development of transportation and mobility systems and is essential for the convenient travel within the country. Furthermore, accurately assessing accessibility in disadvantaged areas is pivotal in designing and implementing development policies for equitable and sustainable transportation systems. Although various methods and tools are available for measuring accessibility, interpreting local-level data remains challenging. This study was conducted in Thailand, a country with severe accessibility disparities but undergoing considerable development. Therefore, the objective of this study was to evaluate accessibility disparities to analyze accessibility capabilities and inequality of railway stations. The objective of the study was to aid the development of inequality and railway services to cover all areas. The geographic information system methodology with network analysis tools was used to visualize and analyze spatial accessibility data and identify regional disparities. The results of this study indicate inequality in accessing railway services, which revealed that densely populated areas have superior access to railway stations compared with districts with a lower population density. Additionally, over 41% of the study area's population resides more than half an hour away from access to a railway station. This study highlights regional inequality in accessing railway station services. Furthermore, strategies to alleviate this inequality are presented and the findings will aid government agencies and railway planners in designing critical strategies or formulating policies for improving accessibility to rail transportation systems and reducing inequality in accessing railway services.

2.2 Introduction

Regardless of the purpose such as tourism, commuting to work, or running personal errands, public transportation is crucial in enabling travel across various areas. Transportation creates employment opportunities within communities, contributing to income generation and improving the quality of life for residents. Public transportation can be categorized into road transportation systems (such as buses) and rail transportation systems (such as trains) (Chang et al. 2019). Rail transportation incurs the lowest travel cost; therefore, it is the most accessible mode of public transportation because of its affordability and higher safety than that of public buses. Train travel is widely popular in many countries owing to its convenience, low travel costs, high safety standards, and timeliness (Feigenbaum 2013). Moreover, the railway transport system is a sustainable transportation system (Dong et al. 2016; Yusoff et al. 2021). However, the development of railway systems has globally attracted considerable attention, specifically in developing countries (Ozawa et al. 2021; Puttanapong et al. 2022; Zafri and Khan 2022) with considerable inequality in people's livelihoods (Suwammolee 2017), particularly in terms of equal access to public transportation systems. Resolving this problem is crucial for the development of the country. Therefore, developing countries emphasize on reducing inequality, with a particular focus on improving public transportation systems, particularly rail transport.

In case of a developing country such as Thailand, the problem of widening disparities in the quality of life for its population remains a challenge that is yet to be adequately addressed. According to statistics from the CS Global Wealth Report, Thailand was identified as a country with high levels of inequality in terms of the quality of life and access to public transportation systems for its citizens (CS Global Wealth Report 2018). The use of railway transportation, including train services, is yet to become popular. The number of train passengers has been declining consistently. In 2021, train passengers decreased by 88.8%, with an average of 138,169 passengers per day, according to the Department of Rail Transport. This decline could be attributed to the limited accessibility of railway routes, primarily due to railway stations being far away from residential areas. Statistics regarding intercity trains indicate that railway routes in Thailand cover only 47 out of 77 provinces, i.e., approximately 61.04% coverage (Annual report 2020).

Nakhon Ratchasima is the largest province in Thailand in terms of area and has the highest number of districts and sub-districts. This province ensures connectivity between the central and northeastern regions of Thailand. This province is a major transportation hub, encompassing land and rail networks. Its comprehensive transportation system positions Nakhon Ratchasima as a pivotal gateway for logistics and distribution of vital goods in the northeastern region of Thailand. In terms of railway station services, Nakhon Ratchasima has the highest number of railway stations in Thailand (Open Government Data of Thailand 2022). However, the distribution of railway stations in the province does not cover all areas, resulting in various groups of population experiencing unequal access to the railway transportation system. Additionally, Thailand's railway network faces several challenges, such as incomplete road networks in certain areas and inability of the public transportation system to provide seamless connections. These problems have multidimensional effects on economy and society. Therefore, studying the accessibility of railway routes and developing a comprehensive railway service that can be accessible to the population in all areas is crucial. Enhancing accessibility to railways can improve living conditions and the quality of life for residents in those areas.

Numerous studies have attempted to analyze accessibility to various amenities, such as spaces within southern China, thereby presenting a model using cellular automata (OS-CA). Open spaces tend to appear near rivers, forests, wetlands, lakes, road intersections, or in proximity to residential areas owing to increasing population rates (Liang et al. 2021). A previous study analyzed accessibility to public parks in Italian cities using different accessibility measures and indicators that consider both supply and demand (Semenzato et al. 2023). The indicators derived from these measures can identify needs, insufficiencies, and inequalities with respect to park accessibility, tested at the municipal level. This study confirmed the necessity of multiple indicators as a planning tool for providing equitable and sufficient access to public open spaces for the population. Furthermore, an analysis of accessibility to healthcare facilities in Hong Kong proposed a geographic information system (GIS)-based model to assess the shortest road travel time to healthcare facilities. The spatial distribution of healthcare facilities in Hong Kong was found to be generally equitable, with patients residing in remote or island areas having limited access and representing a small proportion of the overall population (Zhang et al. 2017). Finally, an analysis of

accessibility to public transportation systems was performed among university students in France using a GIS model to assess the link between environmental factors (natural and built environment) and this accessibility. A strong correlation was found between road density and land use with access to mass transit and public transportation systems. Infrastructure support for active transportation and regulations limiting vehicle speed also play an important role in accessibility (Zannat et al. 2020).

For analyzing accessibility capabilities of rail transport systems, a detailed spatial equity study is necessary for facilitating efficient analysis, improvement, and development of rail transport accessibility (Bröcker et al. 2010; Gutiérrez 2001). Studies focused on reducing spatial disparities in rail transport accessibility have attracted considerable attention. For example, studies have been conducted to improve access routes and reduce spatial disparities in high-speed rail (HSR) systems (Chang and Zheng 2022; Luo and Zhao 2021; Pagliara et al. 2022). Previous studies have examined the accessibility of rail transport systems, particularly by expanding the HSR network, and its effect on surrounding land values (Baş and Delaplace 2021; Wang et al. 2022). The ability to access HSR lines has been studied based on density and economic social equity evaluations (Lee et al. 2018; Miwa et al. 2022) through analysis of spatial disparities at various scales, ranging from the analysis of areas surrounding stations to the regional (S. Liu et al. 2020; López et al. 2008; Wenner and Thierstein 2021) and national (Martí-Henneberg 2013; Mohino et al. 2014; Thevenin et al. 2016) levels.

Furthermore, GIS has been widely used for analyzing the spatial disparities in accessing rail transport systems (Hinners et al. 2022; S. Liu et al. 2020; MartÍn et al. 2004; Morillas-Torné 2012). Studies have revealed geographic barriers in accessing rail services, particularly for individuals residing far from railway stations (Cascetta et al. 2020; Luo and Zhao 2021). Generally, the use of the GIS to measure the geographic accessibility of rail services can be evaluated in terms of both area-based and distance-based approaches (Capodici et al. 2021; Silalahi et al. 2020). Techniques have been proposed to describe and assess the spatial analysis relationships, such as using the public transportation accessibility level index to compare the spatial equity effects considering various service frequencies (Jang et al. 2017). Furthermore, several distance-based approaches have focused on travel time and distance. Most studies have used the straight-line or Euclidean distance to define service areas and measure

spatial barriers between serving railway stations and residential areas (Gutiérrez and García-Palomares 2008; Marques and Pitombo 2021).

In Portland, Oregon, USA, GIS techniques were used to analyze accessibility to the local rail transport system and address accessibility issues for underserved communities (Oh and Wang 2018). Many studies have identified that defining access is related to providing services that can promptly respond to users' requirements (Ashik et al. 2020; Severino et al. 2021). However, solely using the Euclidean distance analysis may not accurately reflect the physical constraints of travel routes. Therefore, studies assessing disparities in accessing railway stations based on road networks typically combine this approach with the aforementioned method for a comprehensive examination of the geographic accessibility concerning transportation modes, road distances, and traffic conditions, which directly affects the travel time required to reach railway stations.

Based on the principle of equal access to railway services, access should remain equitable in case of these services. However, in developing countries, a considerable disparity is observed in accessing rail transport systems that results in an unequal distribution among various groups of people. If opportunities for accessing rail transport systems are distributed evenly, then it can help increase access to railway services for the entire population and reduce inequality gap. This reduction can improve the quality of life and lifestyle as well as effectively satisfy the transportation requirements of the population.

This study is focused on rail accessibility in developing countries and examines spatial disparities by analyzing the accessibility to railway networks in Thailand. Thailand has considerable disparities in accessing rail transport systems, even in provinces with the highest number of railway stations, such as Nakhon Ratchasima, which is the largest province in Thailand. Therefore, this study highlights the areas in which disparities exist and aims to reduce spatial inequalities in accessing railway services for the population in Thailand.

2.3 Methods and Materials

2.3.1 Methodology

Planning a railway transportation system that can serve the majority of the population in the country requires an understanding of the locations of railway stations and accessibility routes to the amenities provided by railway stations. Therefore, GIS technology is a crucial tool that can help analyze data by visualizing them through maps. Furthermore, the results obtained by evaluating the accessibility routes of the railway transportation system to reduce disparities among population can provide considerable insights regarding these disparities.

A literature review revealed that the analysis of access to rail transportation systems depends on the following three key factors, namely the service readiness of railway stations, possible access routes, and the gap between access requirements (Brons et al. 2009; Daniel et al. 2021; Givoni and Rietveld 2007; Semler and Hale 2010; Sidorchuk et al. 2020; Swift et al. 2021). Therefore, the hypothesis of this study is based on the accessibility of railway station services in the study area, which is affected by the disparity caused by the distribution of traditional railway stations. The conditions for accessing railway station services consider the distance traveled on the existing road network. The following methodology was organized to test these hypotheses **Figure 2.1**. First, the spatial distribution of existing railway stations was analyzed (distributional equity). Second, accessibility in terms of travel routes using the road network was analyzed (accessibility). Finally, the disparity in accessing railway stations and the design of strategies to reduce disparities were analyzed. The details of the methodology are explained in the following sections.

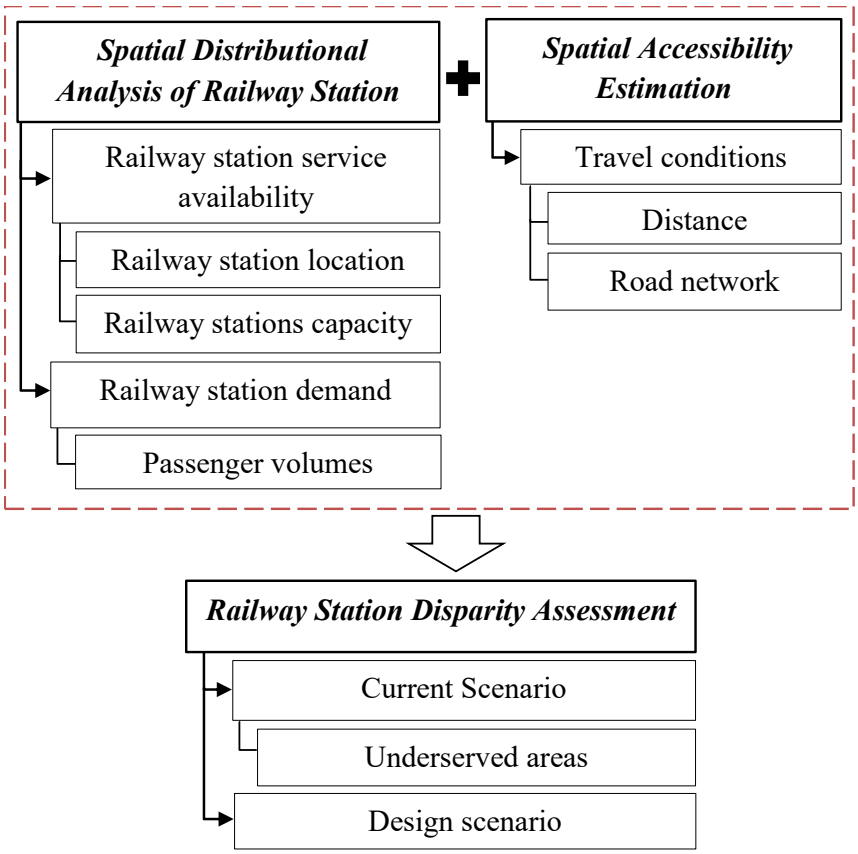


Figure 2.1 Flowchart of the methodology of the study

2.3.2 Spatial Distributional Analysis of Railway Station

Considering the service capability of railway stations is crucial for railway route development planning, as discussed in the previous document. Creating a spatial representation of data is critical for obtaining the existing conditions for further spatial analysis Blainey and Preston 2013; Song et al. 2021; Staněk et al. 2022). Therefore, the spatial mapping method was used to obtain and analyze the spatial distribution of various aspects of railway service capabilities. In this study, data at the sub-district level were used to survey population-related information concerning the service capabilities of railway stations in different areas. In examining the spatial distribution of railway service resources, the first step involves geocoding the railway station data to convert the study areas into x and y coordinates. This initial data were verified for accuracy before further analysis. Subsequently, railway stations with these geographical coordinate codes were integrated with the population density data and the number of passengers and service frequency for each station.

2.3.3 Spatial Accessibility Estimation

We used Dijkstra's algorithm (Dijkstra 2022) to find the shortest path from a starting point to the destination with the closest amenities. In this study, railway stations were used as the nearest amenity. Furthermore, railway stations were used as the destination in GIS, while the central population point created was imported as an event feature for the starting position when calculating the shortest path to the nearest railway station.

In this examination, driving a car is considered the primary mode of accessing the nearest railway station given that cars are the most widely used mode of transportation in Thailand, even in rural areas (Witchayaphong et al. 2020). Furthermore, in accordance with the latest official regulations regarding vehicle speed limits in the rural areas of Thailand stipulating that the speed of small cars must not exceed 120 km/h (Royal Thai Government Gazette 2022), this speed limit is set as the maximum for network analysis in this study.

2.3.4 Railway Station Disparity Assessment

We assessed access to railway stations by combining car travel times and the population's spatial distribution. The Network Analysis tool was used to process travel times in various areas based on their accessibility. First, we categorized travel times into five accessibility levels: within 5, 5–15, 15–30, 30–60, and >60 min. Subsequently, we calculated the population's access to the nearest train station by summing the population figures that can reach the facility using the following equation **(1)**:

$$R_t = \sum P_{s,t} \qquad (1)$$

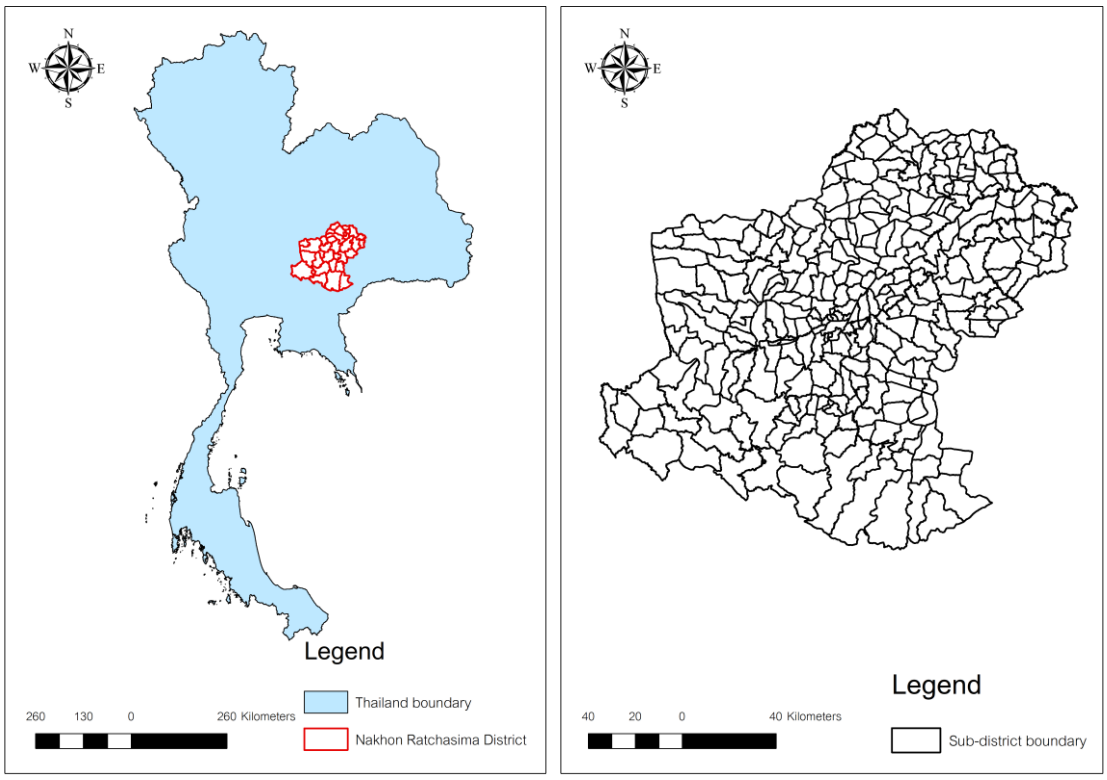
where R_t represents the estimated number of residents who can reach the train station within time t (min) and $P_{s,t}$ represents the population in each sub-district area s capable of accessing the nearest train station within time t. This approach defines different values of t, ranging from 0–5, 5–15, 15–30, 30–60, and >60 min.

2.3.5 Study Area

The Nakhon Ratchasima Province, located in the northeastern region of Thailand, was selected as the study area because it is a crucial link between central and northeastern regions. The northeastern region has the largest population in Thailand; in this region, Nakhon Ratchasima Province has the highest economic development value (GDP). This province is extremely important to Thailand's

transportation system, serving as a gateway connecting travel to the northeast. Nakhon Ratchasima also has a comprehensive mode of transporting people and various goods from the northeast and other regions of Thailand. Additionally, Nakhon Ratchasima is the largest province in Thailand in terms of both land area and administrative subdivisions, with the highest number of districts and sub-districts in the country. According to the statistical registration system in 2022, the province covers an area of more than 20,494 square kilometers. The province has the second-largest population in Thailand, with over 2.3 million inhabitants, resulting in a population density of 114.39 people per square kilometer (Department of Provincial Administration 2022).

This study analyzed train access within Thailand. The country is divided into four administrative levels: national, provincial, district, and sub-district. Therefore, the area-based mapping method used in the study subdivided provincial boundaries into finer details to collect data and assess spatial accessibility; **Figure 2.2** shows these data.



(a) **(b)**

Figure 2.2 Location of study area. (a) Nakhon Ratchasima in Thailand, (b) Sub-district with the largest educational area in Thailand

2.3.6 Collected Data

To evaluate the efficiency of accessibility, spatial distribution must be considered from the perspective of both population and the location of railway stations. Therefore, the data used in this study are obtained from multiple sources. The four essential data categories for this study include (1) population data, (2) boundaries of the study area, (3) railway service utilization data, and (4) road network and amenities data within the area. **Table 2.1** presents detailed information regarding the data sources and their application in this study.

Table 2.1 Collected data for the study

Data	Geographical level	Year	Source
Population data	Province District Sub-district	2022	The official statistics of Thailand
GIS-boundary data	Province boundary District boundary Sub-district boundary	2022	Mitrearth.org
Road network data	Main road national (Highway) Secondary road (Rural road)	2022	Mitrearth.org
Railway data	Province	2022	State Railway of Thailand

The population data in this study was obtained from the Official Statistics Registration Systems, which collects and provides population census data. The population data for the year 2022 was obtained for further analysis based on data availability (Official Statistics Registration Systems (2022). These data were obtained from the provincial administrative units and disaggregated at the district and sub-district levels because this study focused on the dimensions of districts and sub-districts.

The boundaries and geographic data used in this study were obtained from Mitrearth.org, an organization that supports and promotes the use of geospatial data (Pailoplee (2022). Subsequently, this study obtained the boundaries of the study area at the provincial, district, and sub-district levels. Additionally, data on important road networks in Thailand, including the main national highways and secondary rural

roads, was compiled in the .SHP file format. Further processing and analysis was based on these data.

The necessary data on railway service use for this case study, specifically the number of passengers within railway station in Nakhon Ratchasima Province, were collected from the official website of the State Railway of Thailand's Open Railway Government Data (State Railway of Thailand (2022). These data were officially compiled by the State Railway of Thailand.

GIS software was employed, specifically using network analysis, to process data and assess inequalities in accessing railway stations. Geospatial distribution maps were created and the spatial distribution of railway stations and populations in the area were analyzed **Figure 2.3**. Although the distribution of railway stations covers a considerable portion of Nakhon Ratchasima Province, it still does not fully satisfy the travel demands of the entire population.

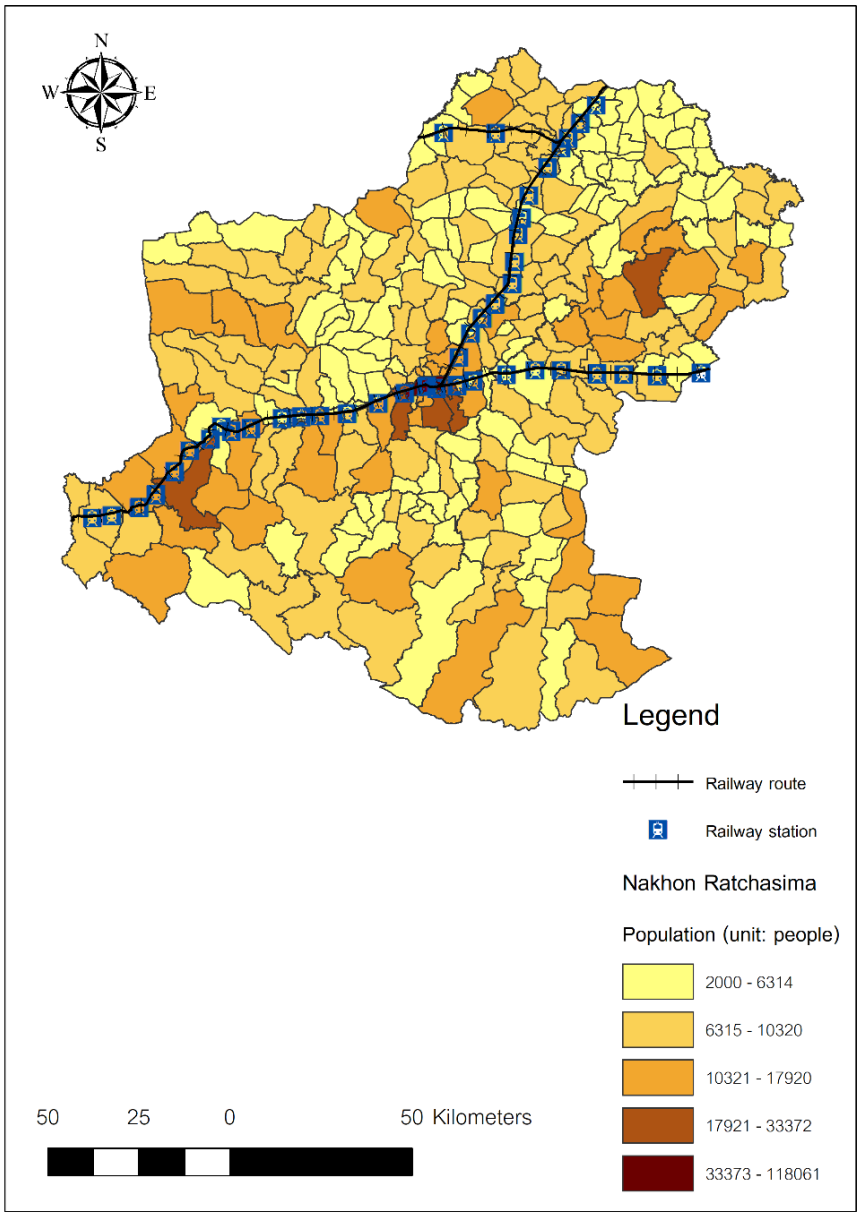


Figure 2.3 Spatial distribution of railway stations and population in the study area, Nakhon Ratchasima

2.4 Results and Discussion

Table 2.2 summarizes information regarding the study area. In the Nakhon Ratchasima Province, only 43 railway stations serve passengers. Based on the population data in 2022, the population was as high as 2.3 million people. The overall area of 20,494 square kilometers is the largest in the country. Moreover, this city has a substantial number of railway passengers, reaching 1.9 million people per year, which

has encouraged the analysis and demonstration of the spatial distribution of railway stations and the travel demands of the population in the study area.

Table 2.2 Statistics data of the study area

Information of study area		**Amount**
Nakhon Ratchasima information	Area (km^2)	20,494
	Population density (people/km^2)	114.39
	Number of district areas	32
	Number of sub-district areas	289
Population information	Total households	904,370
	Total population	2,344,378
	Male	1,153,258
	Female	1,191,120
Railway information	Number of railway stations	43
	Passenger volumes (people/year)	1,996,806

GIS application was used to analyze disparities in accessing railway stations, which were visualized on a map. The study's findings on inequality can be analyzed from various perspectives, which provide additional insights.

2.4.1 Spatial Distributional Analysis of Railway Stations

The understanding of the capabilities or readiness of railway stations in providing services is crucial for passengers or travelers and is particularly critical in the decision-making process of selecting railway services. Therefore, the spatial distribution based on the population density in relation to the railway stations serving the study area, as shown in **Figure 2.4**, indicates the inequality between population density and the capacity or readiness of railway stations in the study area. The distribution of railway stations is yet to be fully covered within the study area. When comparing each administrative sub-district, densely populated areas are predominantly located in urban sub-districts, whereas sparsely populated areas are in rural sub-districts.

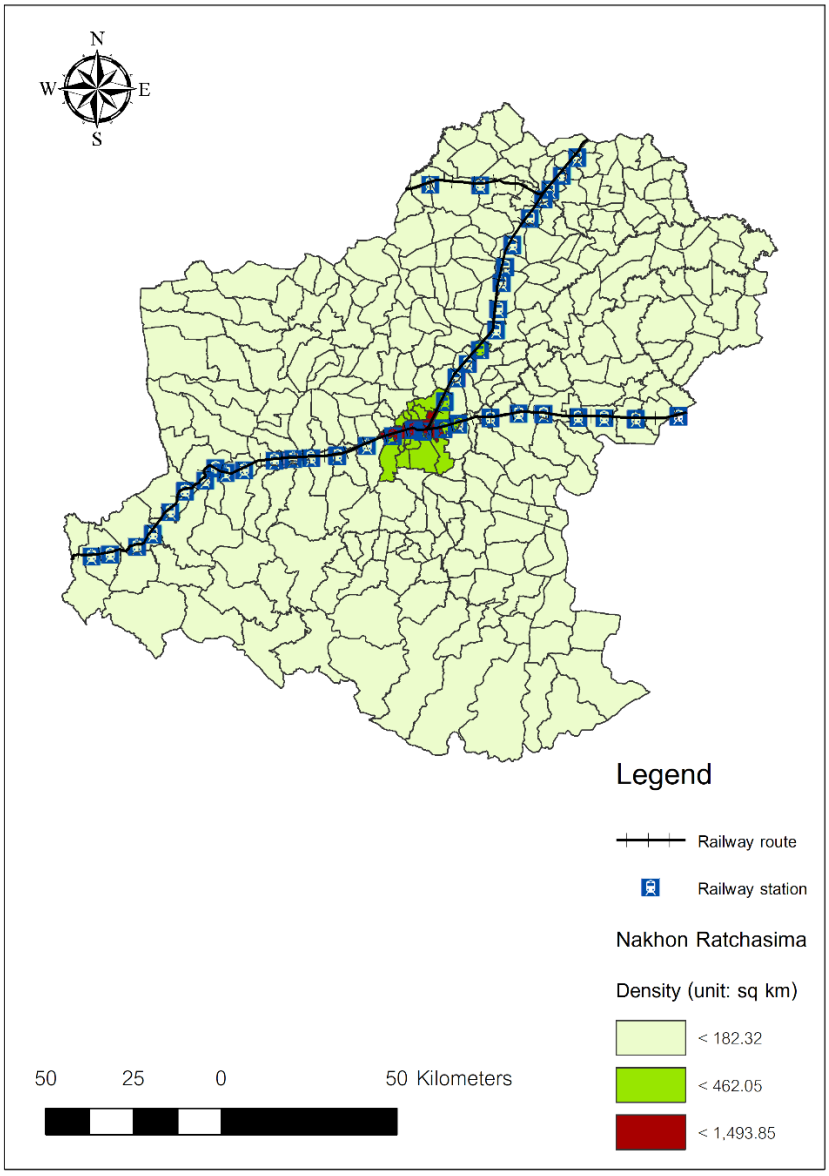


Figure 2.4 Spatial distribution of railway stations and population density within the study area

Considering the travel demand based on the number of passengers per railway station within the Nakhon Ratchasima Province reveals 43 stations with a median value of 12,707 passengers. However, the number of passengers using the services per station varies considerably from 227 to 469,935 individuals per year (represented pink bars in Fig. 5). The distribution shown in **Figure 2.5** indicates that these passenger counts can reflect the accessibility and use patterns of the railway services, with notable disparities between rural and urban areas. Additionally, when

comparing these counts with the expected demand for railway station use obtained from the State Railway of Thailand, the median value is 46,320 passengers, with a fluctuation between 11,459 and 133,898 individuals per year. The spatial disparities in travel demand or service utilization of railway stations is illustrated by blue scale bars, indicating higher passenger counts primarily in urban areas. Conversely, other rural areas exhibit lower or almost negligible demand for station services.

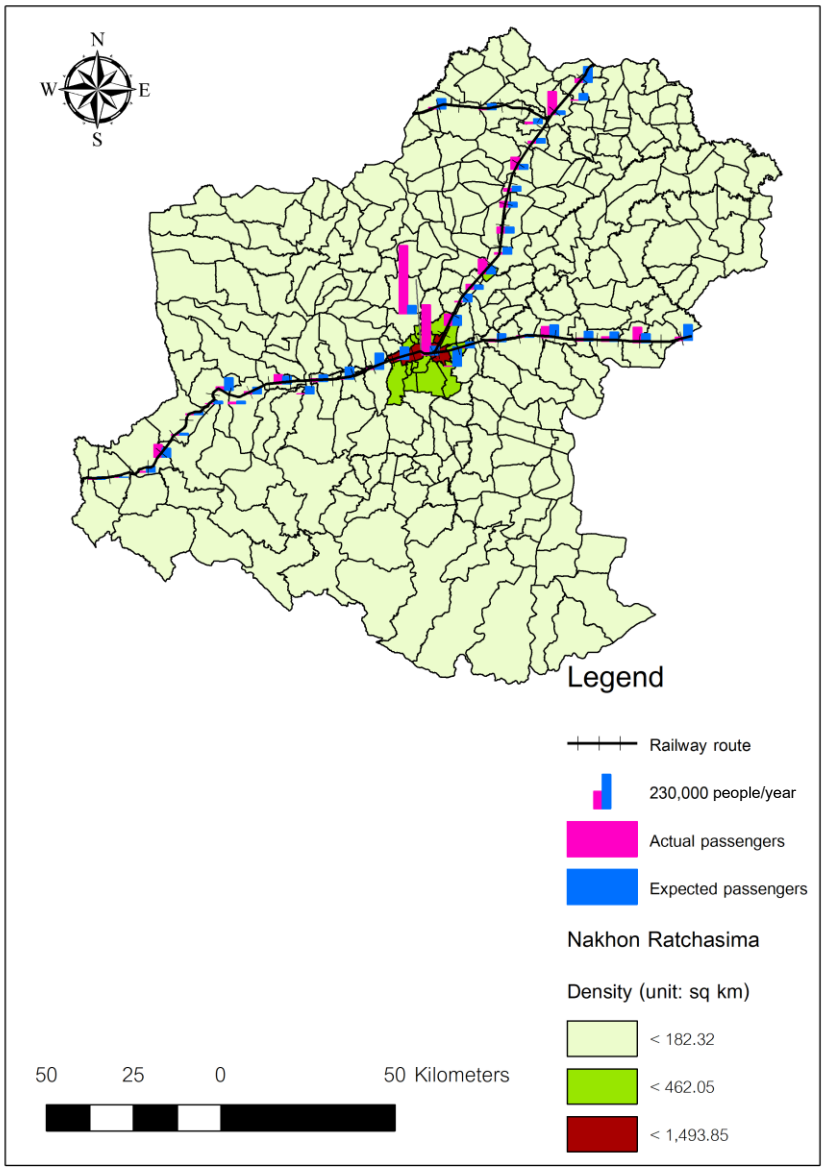


Figure 2.5 Actual passenger volumes and expected demand for railway station use in the study area

Furthermore, train service frequency is another aspect we considered when evaluating the accessibility of railway stations within Nakhon Ratchasima Province. Thailand classifies its railway system into the mainline trains serving interprovincial routes (indicated by yellow bars) and the local trains operating within the province (indicated by purple bars). As shown in **Figure 2.6**, the railway service frequency has a median value of 4 times per day, with the highest frequency reaching 22 times per day and the lowest being 1 time per day. Regarding the railway service frequency, mainline trains (Main Line) have a median frequency of 1 time per day, while local trains (Local Line) have a median frequency of 3 times per day. This observation clearly indicates that in terms of service frequency, railway stations in urban sub-districts generally have higher daily train frequencies compared with those in rural sub-districts.

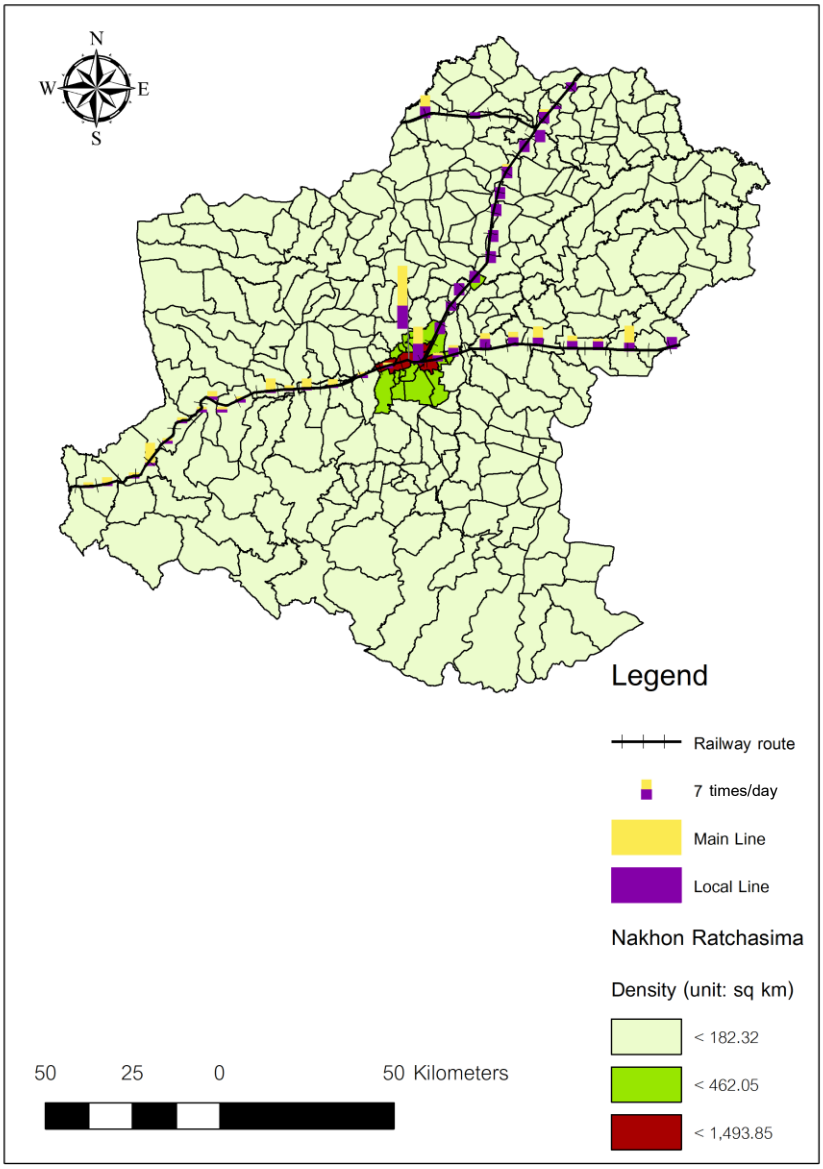


Figure 2.6 Railway service frequencies in the study area

2.4.2 Spatial Accessibility Estimation

According to the literature, the evaluation of the distance to access a railway station is crucial for travelers (Lin et al. 2014; Pinto et al. 2022) because it considerably affects decision-making in selecting the route to reach the train service. Therefore, conducting an analysis of the distance to access the station is highly crucial. The data regarding the distance to access the railway station from the origin within the district shown in **Figure 2.7** indicates the inequality in the distances used to travel to the railway station providing services in the study area. This inequality results in unequal access to the train service.

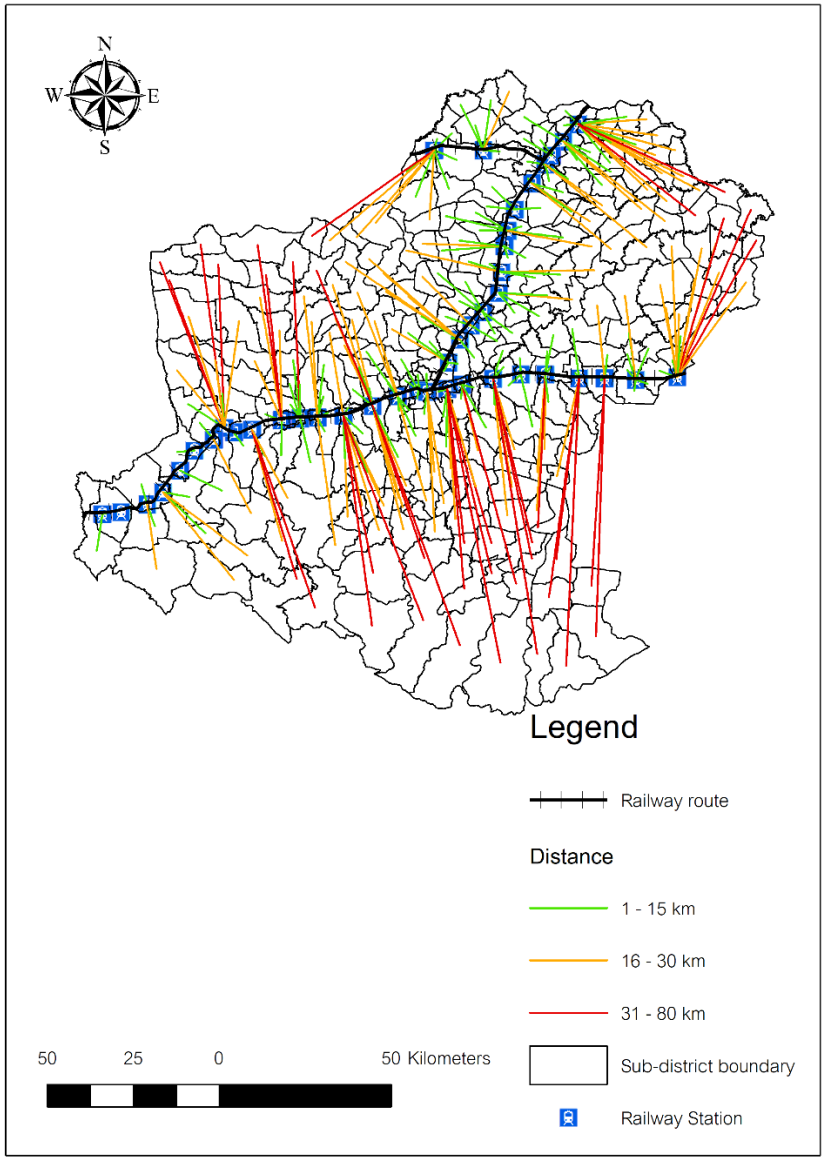


Figure 2.7 Closest distance to access railway stations in the study area

Figure 2.7 illustrates the distances to access railway station from each sub-district, divided into three quantiles used as distance scales. These distances are represented by various colors, with green indicating the closest access distance (1–15 km), orange representing a moderate access distance (16–30 km), and red representing the furthest access distance (31–80 km). Examining each administrative region revealed that on average, only 46% (135 sub-districts) out of all sub-districts within the study area have access routes to railway station within the proximity of 1–15 km. The remaining 54% have access routes to railway station at further distances.

Regarding the analysis of accessibility to the road network using GIS network analysis tools, a survey was conducted to detail the accessibility index based on the travel time **Figure 2.8**. The results of the road network analysis indicate that approximately 42.61% of the covered area, which includes 289 sub-districts, requires more than 60 min of travel time to access the railway station services. **Table 2.3** indicates that accessibility depends on the approximate area and the population's proximity to the nearest railway station within a certain timeframe. Despite the analysis revealing that 20.17%, 19.55%, and 19.37% of the total population in the study area can access the railway station within 5, 10, and 30 min, respectively, a considerable portion of the population, approximately 19.87% and 21.04% (approximately 959,013 people), requires more than 30 min to travel to the railway station.

Table 2.3 Accessibility depends on the approximate area and population in accessing the nearest railway station within a certain time frame

Access duration (min)	Number of sub-districts	Area (km^2)	% Area	Estimated population	% Population
≤5	43	3,010	14.69	472,794	20.17
5–15	42	2,840	13.86	458,452	19.55
15–30	42	2,920	14.25	454,119	19.37
30–60	42	2,990	14.59	465,752	19.87
>60	120	8,734	42.61	493,261	21.04

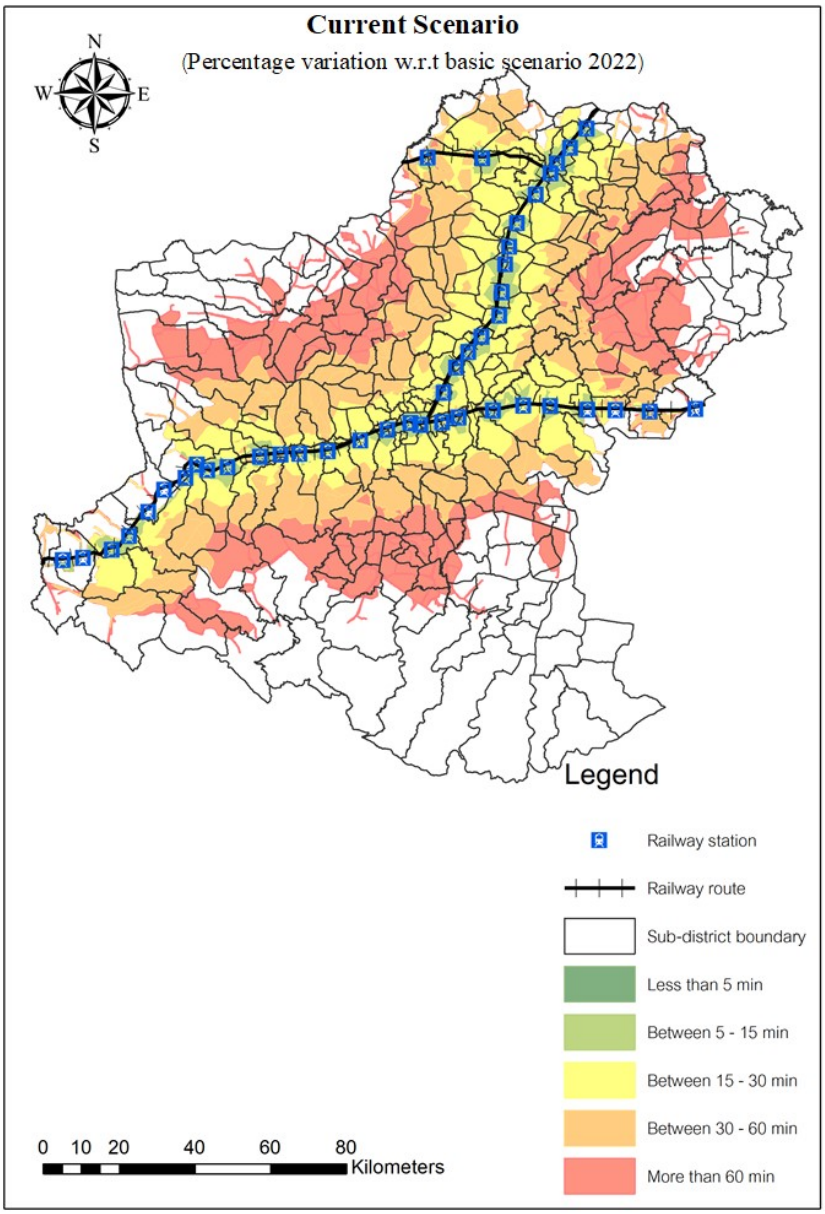


Figure 2.8 Assessing railway station accessibility in the study area using the existing road network

2.4.3 Railway Station Disparity Assessment

Figure 2.8 displays the access of railway stations on the road network of each sub-district categorized into five levels based on the travel time required to reach the railway station as follows: within 5, 5–15, 15–30, 30–60 min, and > 60 min. The map uses a color scheme to represent these different levels, with colors ranging from dark green to red. The darkest red shade represents the area with the longest travel time, which indicates access to railway stations that offer the most time. By contrast,

the white areas represent areas with underserved areas to access the railway, which result in unequal access to railway services within the study area.

Table 2.4 summarizes the results for each district in the study area regarding the spatial inequality in the distribution and accessibility index. Based on the road network analysis, the areas with limited access at the sub-district level are predominantly located in suburban districts, particularly for the residents indicated in white areas in **Figure 2.8**. Assessing this inequality is challenging in terms of the distance and travel time to reach the nearest railway station. To address the inequality in the study area, the assessment results revealed the extent of accessibility disparities at the district level concerning the travel distance required to reach the nearest railway station for using the service. These results exhibit variations in terms of the distance and travel time.

Table 2.4 Ranking of accessibility for each district based on the distance and travel time to the nearest railway station

District no.	Name of district	Number of sub-districts	Total district area (km^2)	Total population (people)	Population density (people /km^2)	Average access distance (km)	Average travel time (min.)
1	Bua Lai	4	106.89	21,432	200.51	7.00	11.50
2	Sung Noen	11	782.85	72,802	93.00	7.91	12.36
3	Ban Lueam	4	218.88	17,156	78.38	9.75	13.25
4	Non Sung	16	676.98	119,153	176.01	11.19	13.50
5	Bua Yai	10	305.03	67,311	220.67	11.50	15.24
6	Huai Thalaeng	10	495.17	70,203	141.78	11.90	15.90
	Mueang						
7	Nakhon Ratchasima	25	755.59	444,958	588.89	12.36	16.80
8	Khong	10	454.74	74,108	162.97	12.50	17.00
9	Chaloem Phra Kiat	5	254.09	31,018	122.07	12.60	17.50
10	Kham Thale So	5	203.60	25,979	127.60	13.60	18.52
11	Chakkarat	8	501.67	67,480	134.51	15.00	20.50
12	Kaeng Sanam Nang	5	107.26	36,487	340.17	16.60	23.40
13	Sikhio	12	1,247.07	100,009	80.20	19.17	24.25
14	Sida	5	162.82	20,004	122.86	19.80	24.60
15	Kham Sakaesaeng	7	297.77	33,299	111.83	23.00	27.29

Table 2.4 Ranking of accessibility for each district based on the distance and travel time to the nearest railway station (Continued)

District no.	Name of district	Number of sub-districts	Total district area (km^2)	Total population (people)	Population density (people /km^2)	Average access distance (km)	Average travel time (min.)
16	Pak Chong	12	1,825.17	159,605	87.45	25.08	29.42
17	Non Thai	10	541.99	62,263	114.88	32.20	33.20
18	Chok Chai	10	503.92	61,511	122.07	32.20	36.00
19	Non Daeng	5	193.48	20,757	107.28	32.60	37.60
20	Prathai	13	600.65	70,878	118.00	34.85	38.15
21	Phimai	12	896.87	119,606	133.36	39.25	40.83
22	Phra Thong Kham	5	359.52	36,590	101.77	45.40	47.60
23	Pak Thong Chai	16	1,374.32	97,078	70.64	45.56	48.19
24	Chum Phuang	9	540.57	73,660	136.26	45.78	49.67
25	Nong Bun Mak	9	590.45	60,611	102.65	49.44	52.44
26	Dan Khun Thot	16	1,428.14	118,384	82.89	54.63	58.31
27	Thepharak	4	357.46	25,351	70.92	69.00	70.50
28	Mueang Yang	4	255.52	27,663	108.26	70.50	71.00
29	Khon Buri	12	1,816.65	80,446	44.28	78.58	81.80
30	Wang Nam Khiao	5	1,130.00	43,767	38.73	86.20	88.83
31	Lam Thamenchai	4	308.46	27,914	90.49	90.00	97.25
32	Soeng Sang	6	1,200.44	56,895	47.40	102.83	111.17

The results of the analysis are calculated using statistical principles and reported in statistical and explanatory reports. **Table 2.5** provides a detailed overview of the declining accessibility to railway stations, which allows us to understand the overall effect. Based on the assessment at the district level, considering factors such as the size of the area, population size, population density, distance to the railway station, and travel time required to reach the railway station. Results reflect the average values of accessibility in terms of both the distance and travel time from residential areas to the railway station in the direction with higher values. This phenomenon leads to a decline in accessing the railway station, creating an inequality in accessing the railway station. This result contradicts the findings of research on the

calculated travel time to access the developed rail transport system in the country, revealing that the travel time should not exceed 30 min to reach the nearest railway station from residential areas (Brons et al. 2009; Cascetta et al. 2020; Gutiérrez 2001; Moyano et al. 2018; Stępniak et al. 2013; Weiss et al. 2018).

Table 2.5 Descriptive statistics analysis

	N	Min	Max	Mean	Std. deviation	Skewness	Kurtosis
Total district Area (km^2)	32	106.89	1,825.17	640.44	483.5102	1.14	0.47
Distance (km)	32	7.00	102.83	35.56	27.10274	1.02	0.06
Travel time (min.)	32	11.50	111.17	39.49	27.10488	1.14	0.51

Accessing public infrastructure, such as railways, has numerous issues, which can result in unequal access. These issues can be attributed to the population concentration in urban areas, as the population size, which influences the development of amenities. Although observed in many countries, such problems are prevalent particularly in developing countries (L. Liu and Zhang (2018). When accessing railway services at a national level, considering governance boundaries, which have railway stations serving specific regions, is essential. Subsequently, the results of this article examine access at the district and sub-district levels. Within the studied area, access to railway stations remains limited. This study emphasized the consequences of accessibility disparities, which typically occur in areas distant from the serving railway stations. Therefore, based on the results, remote or disadvantaged areas within the study region provide valuable data for supporting officials and practitioners involved in railway access route development. These data can be used to reduce gaps in access, contribute to improvement and development efforts, and mitigate accessibility disparities in remote areas of Thailand.

Table 2.6 Improving accessibility through public transportation connections to the nearest railway station within a certain time frame

Access duration (min.)	Number of sub-districts	Area (km^2)	% Area	Estimated population	% Population
≤5	61	4,032	19.67	523,072	22.31
5–15	60	3,868	18.87	499,205	21.29
15–30	69	4,944	24.12	537,206	22.91
30–60	61	4,052	19.77	524,164	22.36
>60	38	3,598	17.56	260,731	11.12

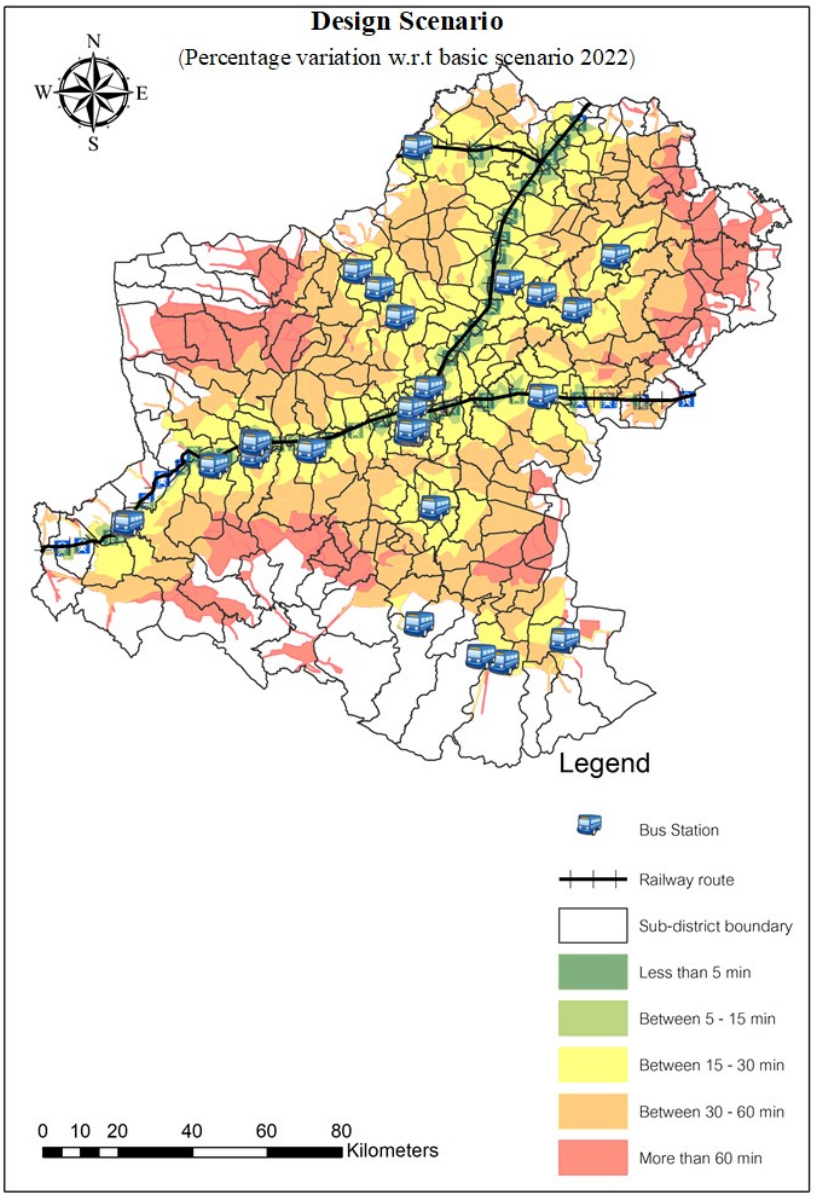


Figure 2.9 Approaches to using regular bus services to connect railway station accessibility in the study area

Therefore, to address inequality issues in accessing railway stations in the study area, researchers have proposed guidelines and designed a scenario **Figure 2.9** to study the reduction of inequality in accessing railway stations in Thailand. The proposed solution involves integrating the existing public bus transportation system to connect with railway stations. Currently, bus routes do not directly connect to the railway stations in the study area. Therefore, this study recommends a solution to reduce inequality by introducing bus routes that link to the railway stations to minimize disparities in access. This solution can facilitate seamless travel and establish various continuous public transportation systems. By implementing the suggested guidelines (**Table 2.6**), only 17.56% of the covered area, comprising 289 sub-districts, would require >60 min of travel time to access the railway station. This result indicates a reduction in the accessibility disparity to railway stations, allowing residents to access the railway station within a better timeframe compared with the current scenario (**Table 2.5**). The outcomes indicate that 22.31%, 21.29%, and 22.91% of the total population in the study area would be able to reach the railway station within 5, 10, and 30 min, respectively. Furthermore, 22.36% and 11.12% of the entire population (approximately 784,895 people) would need to travel more than 30 min to reach the railway station. Implementing these guidelines could reduce the inequality in accessing railway stations by 7.43%.

Enhancing the integration of the bus system with trains is an important strategy for improving accessibility to railway stations in Thailand. This approach promises several benefits, including a more seamless and efficient transportation network, reduced travel times for commuters, and a decrease in accessibility disparities. By connecting existing public bus routes to railway stations (Ghosh et al. 2022), passengers can easily transfer between modes of transportation, leading to more convenient and efficient journeys. This integration not only saves time for passengers but also encourages greater use of public transportation, reducing traffic congestion and benefiting the environment (Mirzahossein et al. 2020; Li et al. 2020). Moreover, it establishes a continuous, integrated public transportation system, simplifying the travel experience for passengers (Solecka and **Ż**ak 2014). Furthermore, the proposed guidelines and scenario for enhancing the bus–train connection can

considerably reduce accessibility disparities, fostering greater equity in transportation access. Thus, local communities can be benefited by providing them better access to essential railway services, particularly residents in less densely populated areas, enabling access to education and job opportunities and promoting social cohesion. Additionally, this approach has positive economic and environmental implications, with the potential to reduce traffic congestion and air pollution, boost local economies, and improve the overall quality of life. In summary, enhancing the bus system to connect with trains aligns with the broader goal of reducing inequality and promoting sustainable transportation systems in Thailand and regions facing similar challenges.

In the context of this study, enhancing the bus system to connect with trains involves several practical steps. The process begins with route planning and integration, where key integration areas are identified and schedules are coordinated with railway operators. Real-time information systems and coordinated schedules ensure timely transfers and minimize waiting times (Nesheli and Ceder 2015). A single-fare system that covers both bus and train journeys simplifies the passenger experience; moreover, accessibility improvements, such as infrastructure enhancements and safety measures, make the system inclusive. Public awareness campaigns educate residents on the benefits of integrated transportation, and public and private stakeholder collaborations are essential. Pilot projects, performance monitoring, and adaptation to local conditions are critical components of this strategy. These measures collectively contribute to a more seamless and efficient transportation network, reduced travel times, and a decrease in accessibility disparities, fostering greater equity in transportation access for local communities in Thailand.

Despite the aforementioned advantages, this study has certain limitations. In particular, the study assessed the accessibility routes to the railway stations using the road network, which only included the national highways and secondary rural roads. This phenomenon can be attributed to data limitations in the study area, making it impossible to consider routes that cover minor roads; thus, the results of the data analysis performed in this study are not applicable to roads that provide access to railway stations through all available routes. In the future, the investigation may be

extended by incorporating data from other road networks, such as local roads and expressways, which would be beneficial for further research for providing a comprehensive assessment of inequality in accessing the actual railway stations. Moreover, future studies should embrace new techniques, including the utilization of extensive data from various sources. This approach will enhance accessibility assessments and enable planning for facility development. Thus, the true extent of inequalities in accessing railway stations can be revealed, leading to a more effective and beneficial development of policies to address railway accessibility disparities.

2.5 Conclusions

In this study, GIS was used to analyze the accessibility of railway stations. The application of geoinformatics techniques, involving network analysis tools and spatial analysis, to study countries such as Thailand with spatial inequality regarding the accessibility of railway stations is highly valuable. Moreover, the integration of data gathered from various sources proves to be particularly beneficial. This approach enables a comprehensive analysis from multiple perspectives, leading to a deeper understanding of the prevailing inequality. The use of GIS demonstrates the procedures and methods for conducting research on the accessibility of railway stations. GIS is an effective tool for spatial inequality analysis and spatial visualization, aiding in the assessment of accessibility disparities when presenting quantitative data. Assessing spatial inequality remains a challenging endeavor, particularly when focusing on the local level. This challenge stems from the fact that individuals at the local level and even those employed within the central railway agency often lack a comprehensive understanding of the research process. Their roles are primarily centered around operational tasks, making them highly proficient only in providing services within railway stations. However, this issue can be mainly attributed to the fact that the analysis of railway development at the local level is not receiving the required research attention. Furthermore, Thailand faces a dearth of similar studies. Therefore, the government of Thailand may not possess the necessary insights for effective railway development in the country, thereby hindering the resolution of local-level inequality issues. Such challenges have been identified and compiled in this study. Furthermore, this study evaluated the accessibility gaps of railway stations in remote areas of Thailand. GIS was used to design an approach for studying the travel time to access

the railway stations on the actual road network and analyze the sub-district level spatial characteristics. This result was performed to identify areas for accessing railway stations within the study area of Nakhon Ratchasima Province, as revealed by the findings of this study.

Based on the findings, certain parts of the city are specifically considered as areas with limited access to railway stations, indicating low accessibility opportunities. Furthermore, the results of inequality are used to rank the areas based on their ability to access railway stations, ranging from the fastest to the slowest within the study area. These results indicate that densely populated districts exhibit a higher likelihood of accessing railway stations compared with districts with a lower population density; over 41% of the study area's population resides more than half an hour away from access to railway stations, leading to unequal accessibility to railway stations. Therefore, this study proposed a solution to mitigate the accessibility disparity of railway stations by integrating bus transportation systems to connect with railway stations for reducing the observed inequality in accessing railway stations (Cascetta et al. 2020; Chan et al. 2021; Herrera-Franco et al. 2022). After this integration, the inequality in accessing railway stations decreased by 7.43%. The GIS approach can be expanded to other regions and perspectives for examining the accessibility disparities of railway stations.

This study effectively presented spatial inequality data on the beneficial accessibility of railway services and provided valuable guidance to formulate strategies for increasing access to railway station services. These strategies can benefit local, national, and even international organizations in designing and implementing measures to reduce accessibility disparities in public infrastructure, such as railway stations. GIS proved to be an effective tool for analyzing and visualizing spatial data, which helped identify key issues affecting access and inequality in accessing railway stations in the remote areas of Thailand. The results of this study provide an excellent foundation for future development and efforts with respect to reducing barriers in accessing essential public services equitably. This study contributes to the development of rail transport systems and reduction in accessibility disparities of public infrastructure, which can lead to a more equitable access to public infrastructure in the future.

2.6 References

Annual report. (2020). State railway of Thailand. Retrieved from https://www.railway.co.th/Home/Index

Ashik, FR., Mim, SA., and Neema, MN. (2020). Towards vertical spatial equity of urban facilities: An integration of spatial and aspatial accessibility. **Journal of Urban Management**, 9(1), 77-92.

Baş, A., and Delaplace, M. (2021). High-speed Rail and Spatial Equity in Developing Countries: The Case of Turkish High-speed Railways.

Blainey, SP., and Preston, JM. (2013). A GIS-based appraisal framework for new local railway stations and services. **Transport Policy**, 25, 41-51.

Bröcker, J., Korzhenevych, A., and Schürmann, C. (2010). Assessing spatial equity and efficiency impacts of transport infrastructure projects. **Transportation Research Part B: Methodological**, 44(7), 795-811.

Brons, M., Givoni, M., and Rietveld, P. (2009). Access to railway stations and its potential in increasing rail use. **Transportation Research Part A: Policy and Practice**, 43(2), 136-149.

Capodici, AE., D'Orso, G., and Migliore, M. (2021). A gis-based methodology for evaluating the increase in multimodal transport between bicycle and rail transport systems. a case study in palermo. **ISPRS International Journal of Geo-Information**, 10(5), 321.

Cascetta, E., Cartenì, A., Henke, I., and Pagliara, F. (2020). Economic growth, transport accessibility and regional equity impacts of high-speed railways in Italy: Ten years ex post evaluation and future perspectives. **Transportation Research Part A: Policy and Practice**, 139, 412-428.

Chan, H-Y., Chen, A., Li, G., Xu, X., and Lam, W. (2021). Evaluating the value of new metro lines using route diversity measures: The case of Hong Kong's Mass Transit Railway system. **Journal of Transport Geography**, 91, 102945.

Chang, Z., Chen, J., Li, W., and Li, X. (2019). Public transportation and the spatial inequality of urban park accessibility: New evidence from Hong Kong. **Transportation Research Part D: Transport and Environment**, 76, 111-122.

Chang, Z., and Zheng, L. (2022). High-speed rail and the spatial pattern of new firm births: Evidence from China. **Transportation Research Part A: Policy and Practice**, 155, 373-386.

CS Global Wealth Report. (2018). Global Wealth Report 2018: US and China in the lead. Retrieved from https://www.credit-suisse.com/about-us-

news/en/articles/news-and-expertise/global-wealth-report-2018-us-and-china-in-the-lead-201810.html

Daniel, CB., Mathew, S., and Subbarayan, S. (2021). GIS-Based Study on the Association Between Road Centrality and Socio-demographic Parameters: a Case Study. **Journal of Geovisualization and Spatial Analysis**, 6(1), 1. doi:10.1007/s41651-021-00095-6

Department of Provincial Administration. (2022). Population Statistics in Thailand. Retrieved from https://www.dopa.go.th/main/web_index

Dijkstra, EW. (2022). A note on two problems in connexion with graphs. **In Edsger Wybe Dijkstra: His Life, Work, and Legacy**, 287-290.

Dong, H., Ma, L., and Broach, J. (2016). Promoting sustainable travel modes for commute tours: A comparison of the effects of home and work locations and employer-provided incentives. **International Journal of Sustainable Transportation**, 10(6), 485-494.

Feigenbaum B. (2013). High-speed rail in Europe and Asia: lessons for the United States. Retrieved from https://reason.org/policy-study/high-speed-rail-in-europe-and-asia/

Ghosh, T., Kanitkar, T., and Srikanth, R. (2022). Assessing equity in public transportation in an Indian city. **Case Studies on Transport Policy**, 10(4), 2337-2349.

Givoni, M., and Rietveld, P. (2007). The access journey to the railway station and its role in passengers' satisfaction with rail travel. **Transport Policy**, 14(5), 357-365.

Gutiérrez, J. (2001). Location, economic potential and daily accessibility: an analysis of the accessibility impact of the high-speed line Madrid–Barcelona–French border. **Journal of Transport Geography**, 9(4), 229-242.

Gutiérrez, J., and García-Palomares, JC. (2008). Distance-measure impacts on the calculation of transport service areas using GIS. **Environment and Planning B: Planning and Design**, 35(3), 480-503.

Herrera-Franco, G., Escandón-Panchana, P., Montalván, FJ., and Velastegui-Montoya, A. (2022). CLUE-S model based on GIS applied to management strategies of territory with oil wells—Case study: Santa Elena, Ecuador. **Geography and Sustainability**, 3(4), 366-378.

Hinners, SJ., Rose, J., Choi, D-a., and Park, K. (2022). Geographically evaluating urban-wildland juxtapositions across 36 urban areas in the United States. **Geography and Sustainability**, 3(2), 139-151.

Jang, S., An, Y., Yi, C., and Lee, S. (2017). Assessing the spatial equity of Seoul's public transportation using the Gini coefficient based on its accessibility. **International Journal of Urban Sciences**, 21(1), 91-107.

Lee, C., Ma, J., and Oh, KK. (2018). Economic impact analysis on regional industries by high-speed rail investments: application of an input-output model. **Transportation Research Record**, 2672(10), 247-259.

Li, S., Lyu, D., Huang, G., Zhang, X., Gao, F., Chen, Y., and Liu, X. (2020). Spatially varying impacts of built environment factors on rail transit ridership at station level: A case study in Guangzhou, China. **Journal of Transport Geography**, 82, 102631.

Liang, X., Tian, H., Li, X., Huang, J-L., Clarke, KC., Yao, Y., and Hu, G. (2021). Modeling the dynamics and walking accessibility of urban open spaces under various policy scenarios. **Landscape and Urban Planning**, 207, 103993.

Lin, TG., Xia, JC., Robinson, TP., Goulias, KG., Church, RL., Olaru, D., and Han, R. (2014). Spatial analysis of access to and accessibility surrounding train stations: A case study of accessibility for the elderly in Perth, Western Australia. **Journal of Transport Geography**, 39, 111-120.

Liu, L., and Zhang, M. (2018). High-speed rail impacts on travel times, accessibility, and economic productivity: A benchmarking analysis in city-cluster regions of China. **Journal of Transport Geography**, 73, 25-40.

Liu, S., Wan, Y., and Zhang, A. (2020). Does China's high-speed rail development lead to regional disparities? A network perspective. **Transportation Research Part A: Policy and Practice**, 138, 299-321.

López, E., Gutiérrez, J., and Gómez, G. (2008). Measuring regional cohesion effects of large-scale transport infrastructure investments: an accessibility approach. **European Planning Studies**, 16(2), 277-301.

Luo, H., ang Zhao, S. (2021). Impacts of high-speed rail on the inequality of intercity accessibility: A case study of Liaoning Province, China. **Journal of Transport Geography**, 90, 102920.

Marques, Sd. F., and Pitombo, CS. (2021). Ridership estimation along bus transit lines based on kriging: Comparative analysis between network and Euclidean distances. **Journal of Geovisualization and Spatial Analysis**, 5(1), 7.

Martí-Henneberg, J. (2013). European integration and national models for railway networks (1840–2010). **Journal of Transport Geography**, 26, 126-138.

MartÍn, JC., Gutiérrez, J., and Román, C. (2004). Data envelopment analysis (DEA) index to measure the accessibility impacts of new infrastructure investments: The

case of the high-speed train corridor Madrid-Barcelona-French border. **Regional Studies**, 38(6), 697-712.

Mirzahossein, H., Rassafi, AA., Sadeghi, K., and Safari, F. (2020). Overview of the Literature on the Transit-Oriented Development to Investigate a Practical Solution for Traffic Congestion in Iran Cities. **International Journal of Transportation Engineering**, 7(4), 355-372.

Miwa, N., Bhatt, A., Morikawa, S., and Kato, H. (2022). High-Speed rail and the knowledge economy: Evidence from Japan. **Transportation Research Part A: Policy and Practice**, 159, 398-416.

Mohino, I., Loukaitou-Sideris, A., and Urena, JM. (2014). Impacts of high-speed rail on metropolitan integration: An examination of London, Madrid and Paris. **International Planning Studies**, 19(3-4), 306-334.

Morillas-Torné, M. (2012). Creation of a geo-spatial database to analyse railways in Europe (1830-2010). A historical GIS approach. **Journal of Geographic Information System**, 2012, núm. 4, p. 176-187.

Moyano, A., Moya-Gómez, B., and Gutiérrez, J. (2018). Access and egress times to high-speed rail stations: a spatiotemporal accessibility analysis. **Journal of Transport Geography**, 73, 84-93.

Nesheli, MM., and Ceder, AA. (2015). Improved reliability of public transportation using real-time transfer synchronization. **Transportation Research Part C: Emerging Technologies**, 60, 525-539.

Official Statistics Registration Systems. (2022). Population Data. Retrieved from https://stat.bora.dopa.go.th/stat/statnew/statMONTH/statmonth/#/mainpage

Oh, S., and Wang, X. (2018). Urban rail transit provides the necessary access to a metropolitan area: a case study of Portland, Oregon, USA. **Urban Rail Transit**, 4, 234-248.

Open Government Data of Thailand. (2022). Railway of Thailand passenger terminal. Retrieved from https://data.go.th/dataset/after16

Ozawa, H., Fukuda, A., Malaitham, S., Vichiensan, V., Luathep, P., and Numa, H. (2021). Evaluation of walking environments around urban railway stations in Bangkok and consideration of improvement plans. **Asian Transport Studies**, 7, 100038.

Pagliara, F., Hayashi, Y., and Ram, KS. (2022). High-Speed Rail, Equity and Inclusion. In (Vol. 14, pp. 6710): MDPI.

Pailoplee, S. (2022) Scope of Thailand country. Retrieved from http://www.mitrearth.org

Pinto, LV., Ferreira, CS. S., Inácio, M., and Pereira, P. (2022). Urban green spaces accessibility in two European cities: Vilnius (Lithuania) and Coimbra (Portugal). **Geography and Sustainability**, 3(1), 74-84.

Puttanapong, N., Luenam, A., and Jongwattanakul, P. (2022). Spatial analysis of inequality in Thailand: Applications of satellite data and spatial statistics/econometrics. **Sustainability**, 14(7), 3946.

Royal Thai Government Gazette. (2022). Ministerial Rule: Set Vehicle Speed on National or Rural Roads. Retrieved from http://www.ratchakitcha.soc.go.th

Semenzato, P., Costa, A., and Campagnaro, T. (2023). Accessibility to urban parks: Comparing GIS based measures in the city of Padova (Italy). **Urban Forestry & Urban Greening**, 82, 127896.

Semler, C., and Hale, C. (2010). Rail Station Access–an assessment of options.

Severino, A., Martseniuk, L., Curto, S., and Neduzha, L. (2021). Routes planning models for railway transport systems in relation to passengers' demand. **Sustainability**, 13(16), 8686.

Sidorchuk, R., Skorobogatykh, I., Lukina, A., Mkhitaryan, S., and Stukalova, A. (2020). Access to the rail station as a customer value: Simulation of passenger flows in rail stations with disinfection gateway installations. **Journal of Open Innovation: Technology, Market, and Complexity**, 6(4), 122.

Silalahi, FE. S., Hidayat, F., Dewi, RS., Purwono, N., and Oktaviani, N. (2020). GIS-based approaches on the accessibility of referral hospital using network analysis and the spatial distribution model of the spreading case of COVID-19 in Jakarta, Indonesia. **BMC health services research**, 20(1), 1-20.

Solecka, K., and **Ż**ak, J. (2014). Integration of the urban public transportation system with the application of traffic simulation. **Transportation Research Procedia**, 3, 259-268.

Song, T., Pu, H., Schonfeld, P., Zhang, H., Li, W., Peng, X., and Liu, W. (2021). GIS-based multi-criteria railway design with spatial environmental considerations. **Applied Geography**, 131, 102449.

Stan**ě**k, K., Šilhák, P., and Ryglová, A. (2022). A Graphical Generalization of Localized Morphological Discontinuities on Medium-Scale State Topographic Maps. **Journal of Geovisualization and Spatial Analysis**, 6(2), 20.

State Railway of Thailand. (2022). Service statistics. Retrieved from https://www.railway.co.th/AboutUs/Performance_detail?value1

St**ę**pniak, M., Rosik, P., and Komornicki, T. (2013). Accessibility patterns: Poland case study. **Europa Xxi**, 24, 77-93.

Suwammolee, S. (2017) Inequality Pathway of Rawai Sea Gypsies in Phuket Province. **Research journal Walailak University**, 10(1), 90-96.

Swift, A., Cheng, L., Loo, BP., Cao, M., and Witlox, F. (2021). Step-free railway station access in the UK: the value of inclusive design. **European Transport Research Review**, 13(1), 1-12.

Thevenin, T., Mimeur, C., Schwartz, R., and Sapet, L. (2016). Measuring one century of railway accessibility and population change in France. A historical GIS approach. **Journal of Transport Geography**, 56, 62-76.

Wang, Y., Ruan, H., and Tian, C. (2022). Access to high-speed rail and land prices in China's peripheral regions. **Cities**, 130, 103877.

Weiss, DJ., Nelson, A., Gibson, H., Temperley, W., Peedell, S., Lieber, A., and Fullman, N. (2018). A global map of travel time to cities to assess inequalities in accessibility in 2015. **Nature**, 553(7688), 333-336.

Wenner, F., and Thierstein, A. (2021). Rail accessibility in Germany: changing regional disparities between 1990 and 2020. **Raumforschung und Raumordnung/Spatial Research and Planning**, 79(2), 95-115.

Witchayaphong, P., Pravinvongvuth, S., Kanitpong, K., Sano, K., and Horpibulsuk, S. (2020). Influential factors affecting travelers' mode choice behavior on mass transit in Bangkok, Thailand. **Sustainability**, 12(22), 9522.

Yusoff, I., Ng, B.-K., and Azizan, SA. (2021). Towards sustainable transport policy framework: A rail-based transit system in Klang Valley, Malaysia. **PloS one**, 16(3), e0248519.

Zafri, NM., and Khan, A. (2022). A spatial regression modeling framework for examining relationships between the built environment and pedestrian crash occurrences at macroscopic level: A study in a developing country context. **Geography and Sustainability**, 3(4), 312-324.

Zannat, KE., Adnan, MSG., and Dewan, A. (2020). A GIS-based approach to evaluating environmental influences on active and public transport accessibility of university students. **Journal of Urban Management**, 9(3), 331-346.

Zhang, W., Cao, K., Liu, S., and Huang, B. (2017). GIS-Based Accessibility Analysis of Health-Care Facilities: A Case Study in Hong Kong. **Comprehensive Geographic Information Systems**.